

DRAFT

Deepwater Horizon/Mississippi Canyon 252 Oil Spill Report on Submerged Aquatic Vegetation Residing in Jean Lafitte National Historic Park and Preserve

Natural Resource Damage Assessment

Prepared for:

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and

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ABBREVIATIONS AND ACRONYMS

DO Dissolved Oxygen

FAV Floating Aquatic Vegetation
GPS Global Positioning System
HDPE High-Density Polyethylene

ID Identification

JELA Jean Lafitte National Historical Park and Preserve

LA Louisiana

MC 252 Deepwater Horizon/Mississippi Canyon 252 NOAA National Oceanic and Atmospheric Administration

NRDA National Resource Damage Assessment
PAH Polycyclic Aromatic Hydrocarbon
SAV Submerged Aquatic Vegetation

TN Total Nitrogen TP Total Phosphorous

USEPA U.S. Environmental Protection Agency

USGS U.S. Geological Survey VOC Volatile Organic Compound

UNITS OF MEASURE

°C degrees Celsius cm centimeters

ft³/s cubic feet per second

L liter

mg/L milligram per liter

mL Milliliter

mS/cm milli-Siemens per centimeter NTU nephelometric turbidity unit

oz ounce

ppt parts per thousand

1.0 INTRODUCTION

In response to the Deepwater Horizon/Mississippi Canyon 252 (MC 252) Oil Spill, Mississippi River freshwater flows were diverted from the Davis Pond Diversion to Lake Cataouatche to reduce the potential for oil intrusion into the inland marshes, including Jean Lafitte National Historical Park and Preserve (JELA) (Figure 1-1). As a result, the submerged aquatic vegetation (SAV) community at JELA may have been impacted by the increase in freshwater and nutrients into the interior marshes. Potential effects of increased freshwater and nutrients include diminished water quality and eutrophication. These changes in the physical habitat may result in reductions in the diversity and abundance of SAV species and proliferation of nuisance algal blooms (Harlin, 1995). Additionally, the loss of SAV and proliferation of dense floating aquatic vegetation (FAV) can result in habitat degradation and impacts to fish and wildlife (Poirrier et al., 2009).

SAV communities are known to be sensitive to slight changes in physical water quality conditions (Davis and Brinson, 1980; Dennison et al., 1993). Sustained changes in salinity can alter SAV community composition since salinity tolerances are highly species specific (Poirrier et al., 2010). Consequently, salinity is considered to be the primary factor that controls SAV community structure in coastal Louisiana (Cho and Poirrier, 2005). Additionally, increases in turbidity and associated reductions in light penetration within the water column can favor floating aquatic plants as well as surface-mat forming species of SAV, which can lead to the competitive exclusion of species that recruit opportunistically (Poirrier et al., 2009).

Previous studies have shown that increased nutrients to lakes result in reductions in SAV due to increased density and abundance of phytoplankton and algal epiphytes (Kalff, 2002). In Lakes, shifts from SAV-dominated communities to phytoplankton-dominated communities can occur with nutrient addition (Dodson et al., 2005). Similarly, in marine and estuarine communities, SAV is replaced by macroalgae with nutrient addition (Day et al., 1989). One means of controlling unwanted SAV in warm-water farm ponds is to add fertilizer to produce algal blooms in early spring that shade new SAV growth from the bottom (Poirrier, personal communication). Based on fundamental SAV ecology, high loading of nitrogen and phosphorus from the increased Mississippi River flow through the Davis Pond Diversion has the potential to adversely affect the SAV community in JELA.

Aquatic habitats throughout JELA were recently surveyed from June 2006 through April 2008 by Poirrier et al. (2010) to determine the community composition, distribution, and abundance of SAV. The waters within JELA were found to range from freshwater to low-salinity, brackishwater, and supported ten SAV species within ponds, canals, and Lake Cataouatche. Seven of the ten species were determined to be native species: Cabomba caroliniana, Ceratophyllum demersum, Heteranthera dubia, Najas guadalupensis, Potamogeton pusillus, Vallisneria americana, and Zannichellia palustris, while the remaining three species were categorized as exotic: Egeria densa, Hydrilla verticillata, and Myriophyllum spicatum. The Poirrier et al. study provides a baseline assessment of the JELA SAV community prior to the increased diversion of Mississippi River water into JELA as a response to the MC 252 Oil Spill. By performing a similar study of the JELA SAV community accompanied by assessment of physical and chemical water quality parameters using methods that are consistent with the prior Poirrier et al.

study, potential impacts of the sustained diversion of Mississippi River freshwater into JELA can be assessed.

1.1 Objective

The purpose of the study was to assess the potential impacts of increased freshwater inputs into JELA in response to the MC 252 Oil Spill. Potential physical aquatic habitat impacts include alterations of physical and chemical habitat quality, including increased nutrient concentrations, salinity reductions, and reduced light penetration. These water quality changes have the potential to affect the JELA SAV community, resulting in shifts in the relative abundance of species, including increases in the abundance of exotic species and FAV. Field surveys of JELA Bayou des Allemands and Humble Canal reference area aquatic habitats were conducted in September 2010 to assess water quality conditions and SAV community composition using methods consistent with the Poirrier et al. baseline study (2009). This allowed for a before-after comparison of the JELA SAV community to assess potential MC 252 response secondary impacts.

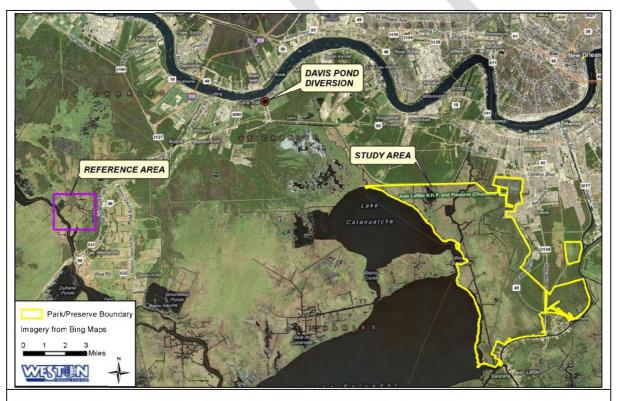


Figure 1-1. Overview of Jean Lafitte National Historical Park and Preserve Study Area and Stations.

2.0 METHODS

Field surveys were conducted within JELA and at a reference area outside of JELA from September 7, 2010 through September 11, 2010. Surveys included assessments of SAV species composition at 36 stations within the northeast portion of the Barataria Estuary in JELA and at 5 reference stations positioned within Bayou des Allemands and Humble Canal north of the Davis Pond Diversion in areas not subjected to increased freshwater intrusion (Figure 1-1). Determination of the number of stations surveyed within JELA was based on the U.S. Environmental Protection Agency's (USEPA's) *Guidance for the Data Quality Objectives Process* (USEPA, 2006a) and *Data Quality Assessment: Statistical Methods for Practitioners* (USEPA, 2006b).

Determinations of the relative abundance and distribution of native, exotic, and nuisance SAV, as well as macroalgae, FAV, and emergent aquatic plants, were performed at all stations using methods consistent with the JELA baseline Poirrier et al. study (2009). Physical water quality parameters were also measured at all JELA stations. Surface water, sediment, and SAV tissue samples were collected at 10 of the 36 JELA stations for chemical analyses, including polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs) and nutrients (total nitrogen [TN] and total phosphorous [TP] within water and sediment). Water and sediment samples were also collected for nutrient analysis (TN and TP) at the five (5) reference stations.

Shallow-draft vessels (airboats and duck boats) that could access stations throughout JELA were used to perform the SAV surveys (Figure 2-1). The field crew consisted of five to six personnel over the five-day sampling period, including Dr. Mike Poirrier – field lead familiar with the SAV survey protocols and local species; Brian Riley and Dan McCoy – field scientists with experience in SAV surveys, water quality sampling, and water, sediment, and tissue sampling; Dusty Pate, Kelly Altenhofen, and Karl Carlson – National Parks Service park rangers familiar with JELA; and a responsible party representative.



Figure 2-1. Air Boat and Shallow Draft Boat Sampling Vessels

2.1 Station Locations

Ten targeted stations (Stations 1-10) within the northeastern portion of the Barataria Estuary in JELA were surveyed for SAV and FAV; physical water quality parameters and water, sediment, and SAV tissue chemistry. Water, sediment, and SAV tissue samples were collected for analysis of PAHs and VOCs in the event of oiling at JELA. Additional water and sediment samples were collected for analysis of TN and TP. Twenty six additional JELA stations (Stations 11-36) were assessed for SAV and physical water quality (Table 2-1, Figure 2-2). Stations were positioned in areas of JELA that previously had been found to support SAV, including the lake shorelines and inland channels. Additionally, five reference stations positioned within areas north of the Davis Pond freshwater diversion were surveyed for SAV and FAV, physical water quality parameters, and water and sediment nutrients (TN and TP) (Figure 2-3). Stations were defined to be areas of approximately 50 m² that occurred along shorelines and were likely to support SAV.

Table 2-1. Stations and Types of Sampling Performed.

Station	Water Body	Latitude	Longitude	Water, Sediment, & Tissue Sample ¹	SAV Assessment	Physical Water Quality	Photo and GPS Documentation
1	Bayou Segnette	29.84868	-90.17147	X	X	X	X
2	Tarpaper Canal	29.83468	-90.15472	X	X	X	X
3	Parallel Canal	29.82385	-90.12327	X	X	X	X
4	Pipeline Canal	29.77149	- 90.14011	X	X	X	X
5	Lower Kenta Canal	29.77394	-90.11115	X	X	X	X
6	Bayou Segnette Waterway	29.74202	- 90.14191	X	X	X	X
7	Bayou Segnette Waterway	29.79626	-90.16219	X	X	X	X
8	Lake Salvador	29.80490	-90.16862	X	X	X	X
9	Bayou Bardeaux	29.81844	-90.16347	X	X	X	X
10	Lake Cataouatche	29.84334	-90.19146	X	X	X	X
11	Horseshoe Canal	29.84441	- 90.14751		X	X	X
12	Horseshoe Canal	29.84799	-90.14327		X	X	X
13	Bayou Boeuf	29.84390	-90.15637		X	X	X
14	Tarpaper Canal	29.81397	-90.12721		X	X	X
15	Pipeline Canal	29.78840	-90.13789		X	X	X
16	Bayou des Familles	29.78804	-90.07485		X	X	X
17	Kenta Canal	29.77721	-90.07310		X	X	X
18	Kenta Canal	29.76833	-90.10720		X	X	X

Station	Water Body	Latitude	Longitude	Water, Sediment, & Tissue Sample ¹	SAV Assessment	Physical Water Quality	Photo and GPS Documentation
19	Pipeline Canal	29.78662	-90.13634		X	X	X
20	Lake Salvador	29.78609	-90.08852		X	Х	X
21	Lake Salvador	29.75728	-90.15387		X	Х	X
22	Lake Cataouatche	29.86887	-90.23629		X	Х	X
23	Lake Cataouatche	29.86118	-90.21838	d	X	Х	X
24	Lake Cataouatche	29.83181	-90.18000		X	Х	X
25	Tarpaper Canal	29.80821	-90.12647		X	X	X
26	Kenta Canal	29.84260	-90.17283		X	X	X
27	Bayou Segnette Waterway	29.74565	-90.15247		X	X	X
28	Parallel Canal	29.82463	-90.12249		X	X	X
29	Kenta Canal	29.79054	-90.13033		X	X	X
30	Pipeline Canal	29.76074	-90.14570		X	X	X
31	Lake Salvador	29.83225	-90.1659 2		X	Х	X
32	Lake Salvador	29.80436	-90.18500		X	X	X
33	Bayou Bardeaux	29,81702	-90.17032		X	X	X
34	Davis Marrero Canal	29.83339	-90.15176		X	X	X
35	Yankee Pond	29.85033	-90.17363		X	X	X
36	Lake Cataouatche	29.84257	-90.18951		X	X	X
R1	Humble Canal	29.85936	-90.47194	X	X	X	X
R2	Bayou des Allemands	29.85770	-90.48682	X	X	Х	X
R3	Bayou des Allemands	29.84702	-90.48385	X	X	X	X
R4	Humble Canal	29.86502	-90.46877	X	X	Х	X
R5	Humble Canal	29.85659	-90.46111	X	X	X	X
1						-	:

¹ Water and sediment samples were only collected for nutrient analyses at reference locations.



Figure 2-2. Jean Lafitte National Historical Park and Preserve Study Area

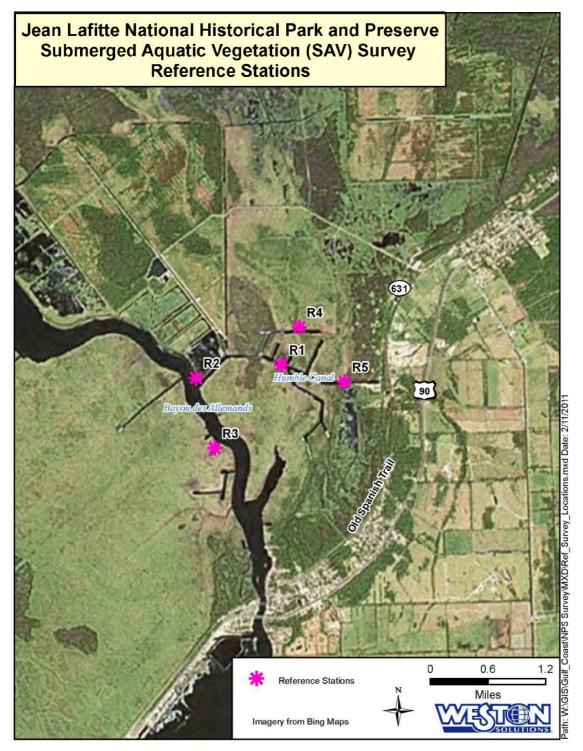


Figure 2-3. Bayou des Allemands and Humble Canal Reference Area

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2.2 Station Characterization

The field crew performed station assessments consistent with National Resource Damage Assessment (NRDA) protocols. A global positioning system (GPS) unit recorded the latitude and longitude of stations; photographs were taken to record general habitat characteristics; physical water quality and SAV community assessments were performed; and water, sediment, and tissue samples were collected as detailed in the following sections.

2.2.1 GPS Locations

Stations were positioned as close as possible to preselected GPS locations; however, some stations were relocated due to limited accessibility. The station name (general geographic location or established sampling area) along with latitude and longitude obtained via a handheld GPS were noted. Coordinates were recorded in decimal degrees with WGS84 as the datum and each station was recorded as a waypoint with the GPS unit. Photographs were taken of the GPS unit, with the date and time visible, at each station in accordance with NRDA protocol.

2.2.2 Photographs

Photographs were taken of each station to record existing conditions at the time of the assessment. Photographs were taken in a series throughout each day so that they could later be sequentially associated with the corresponding sampling locations (e.g., through use of GPS Photolink software or by keeping a detailed photo log) per the NRDA Field Photography Guidance document. No pictures were deleted or altered in accordance with NRDA protocols.

At the conclusion of the study, all photographs were logged into the National Oceanic and Atmospheric Administration (NOAA) NRDA Trustees Sampler Photo Logger Form. Original photo files were uploaded to a computer hard drive and not opened. The original photo files were ultimately relinquished to NRDA personnel with all required Chain of Custody forms.

2.3 Physical Water Quality Assessment

Following initial assessment of the station to establish the presence of SAV and completion of the Site Characterization Form, the field crew performed physical water chemistry measurements for pH, dissolved oxygen (DO), temperature, salinity, conductivity, water depth, turbidity, and light penetration (i.e., Secchi depth). Water quality assessments were completed upon arrival at the site to avoid suspension of sediments within the water column from other assessment activities.

Light penetration was measured using a Secchi disk, a round black and white weighted disk that was lowered through the water until the distinction between white and black quadrants was no longer visible to the human eye. The disk was attached to a non-stretching rope, marked at 10-cm intervals. The disk was lowered slowly over the side of the boat facing the sun and not in the shadow of the vessel, until the disk disappeared; it was then raised until it reappeared. The depth at which the disk reappeared was recorded onto a field sheet. At the time of the measurement, the time of day and cloud cover were also recorded. Secchi depth provides a measure of the

light-limited colonization depth of SAV species (Poirrier et al., 2009) because transparency readings approximately equate to 10% of surface light (Wetzel, 2001).

Water quality measurements for DO, pH, turbidity, temperature, conductivity, and salinity were measured using a pre-calibrated YSI 6920 data sonde. At each station, the sonde was lowered approximately two feet below the water's surface and allowed to equilibrate. Dissolved oxygen was recorded in milligrams per liter (mg/L), turbidity was recorded in nephelometric turbidity units (NTU), salinity was recorded in parts per thousand (ppt), conductance was recorded in milli-Siemens per centimeter (mS/cm), pH was measured in pH units, and temperature was recorded in degrees Celsius (°C). All values were recorded onto SAV Site Characterization data sheets.

2.4 SAV Characterization

Characterization of SAV began with an initial visual assessment of presence of SAV, FAV, and emergent plant species at each station (Figure 2-4). SAV characterizations were performed within three shoreline quadrats at each station. The approximately 12-m² quadrat consisted of the area immediately surrounding the boat (1.5 m x 4 m on either side of the boat).

2.4.1 SAV Assessment of Species Relative Abundance

Three representative quadrats were chosen at each of the stations to conduct SAV Within each quadrat, the assessments. species composition of a given SAV bed was determined by both inspecting SAV species that could be seen growing at, or just below, the water's surface and by using a long-handled 5-ft rake to collect SAV growing below the depth at which species could be clearly seen. FAV associated with beds were recorded for each quadrat as well as the approximate percent coverage of floating vegetation over the entirety of the quadrat. Any flowering shoots observed on SAV were recorded onto field data forms and digital photographs were taken to document observed SAV species.



Figure 2-4. A SAV bed of *Cabomba caroliniana* growing at the water's surface.

2.5 Chemistry Sampling

Chemistry water, sediment, and SAV tissue samples were collected from the 10 targeted JELA stations and five reference stations. Water, sediment, and SAV tissue samples were collected at the 10 JELA targeted stations for analysis of PAHs and VOCs in the event of oiling at JELA. Separate water and sediment samples were collected for analysis of TN and TP at the 10 targeted JELA and five reference stations. Sediment, water, and tissue sampling for analyses of PAHs followed established procedures provided by the SAV Technical Working Group in the Mississippi Canyon 252 Incident SAV Tier 1 Pre-Assessment Plan Pre-Impact Baseline Characterization and described in the approved Sampling and Analysis Plan.

2.5.1 Water Chemistry Sampling

Water chemistry and water nutrient samples were collected by lowering the appropriate sample bottle below the surface of the water and allowing the water flow directly into the sample container to cross-contamination. minimize the risk of Subsurface sample containers were deployed and retrieved with the lid sealed so that the sample did not. inadvertently include surface constituents. Water samples for PAH analysis were collected in 1-L amber glass sampling containers with Teflon-lined lids, certified clean for semivolatile analysis. Water nutrient samples were collected in 60-mL high-density polyethylene (HDPE) sample bottles. Water samples for PAH analyses were collected such that approximately 1 inch of headspace remained in the sample bottle when filled. Water nutrient sample bottles were filled halfway, providing approximately 30 mL of sample.

For the collection of VOC water samples, a clean 1-L amber bottle was submerged, opened, closed, and retrieved from below the surface of the water. Water from this container was then poured into a



Figure 2-5. Sediment sampling with Ponar grab sampler.

certified clean, laboratory VOC vial containing 0.2 mL hydrochloric acid as a preservative. VOC samples were filled above the vial opening so that when the cap was placed onto the vial, no headspace or air bubbles remained after cap was replaced.

Sample ID labels were affixed to each container and covered with clear tape wrapped around the entire container circumference. Following labeling, sample containers were immediately placed inside a cooler on ice.

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2.5.2 Sediment Chemistry

A ponar grab sampler was used to collect sediment samples from each of the 10 targeted sampling stations (Stations 1-10) (Figure 2-5). The ponar grab sampler and stainless steel mixing bowl and spoon were decontaminated prior to use at each of the sampling stations using laboratory-grade detergent (Alconox), followed by rinsing with site water. The ponar grab

sampler was lowered to the sediment at a controlled speed of approximately 1 foot per second to minimize disturbance of any flocculent material on the sediment surface. Only the weight of the sampler was used to penetrate the sediment. The ponar grab sampler was inspected upon retrieval to ensure the sampler was not overfilled and that the sediment surface was not pressed against the sampler top. Grab samples were deemed to be acceptable if overlying water was present, indicating minimal leakage and retention of flocculent material; sediment surface was undisturbed, indicating lack of channeling or sample washout; and the desired penetration depth was achieved (e.g., 4-5 cm for a 2-cm sample).



Figure 2-6. Homogenized sediment sample prior to being placed into a glass jars for sediment chemistry and nutrient analysis.

Overlying water was drained from the sampler until the sediment was exposed. Special attention was paid while draining water to ensure retention of any surface flocculence. Once the overlying water was drained from the sample, a stainless steel spoon was used to collect the top 2-cm layer into a stainless steel mixing bowl. Sediments in direct contact with the sides or top of the sampler were avoided. Sediment was homogenized in the mixing bowl using the stainless steel spoon (Figure 2-6) and subsequently transferred into appropriate containers (8-oz glass jars with Teflon lids) for sediment nutrient and sediment chemistry analyses and Ziploc bags for grain size analyses). Sediment samples were labeled and immediately placed into a cooler and kept on ice. Samples were delivered to Sample Intake personnel within 5 days of collection.

2.5.3 SAV Tissue Chemistry Sampling

Vegetation tissue samples were collected for all species of SAV (Figure 2-7) encountered at the targeted stations (Stations 1-10), with the exception of species for which an adequate amount of tissue could not be collected. Vegetation samples for hydrocarbon analysis were collected in 250-mL (8-oz) wide-mouth glass jars (certified clean to be organic free) (Figure 2-8). The minimum target sample volume for vegetation was 30 grams (wet weight) although 50 grams was more desirable. Tissue chemistry jars were comprised of a composite of a sufficient number of individuals of a given SAV species to fill the sample jars approximately 3/4 full. Excess sediment that had adhered to vegetation was physically removed or avoided to the degree practical. All tissue samples were immediately placed into a cooler and stored on ice at 4°C.





Figure 2-7. SAV tissue sample of *Hydrilla verticillata*.

Figure 2-8. SAV tissue sample after being placed into a jar for tissue analysis.

2.6 Sample Collection Documentation

Sample collection documentation was performed in accordance with the instructions in the NOAA Field Sampling Workbooks (available on the case's file transfer protocol site). Sample Identification (IDs) were listed under each category of sample types. If no samples of a given type were taken, "none was entered. Sample labels were prepared following the sample ID protocol provided in the instructions from the trustee data management team contained the following information:

- Location code (e.g., LAAN37 for Louisiana grid section 37)
- Letter indicating the study year that the sample was collected (e.g., A for the first year, B will be the second year, etc.)
- Month and day of collection (e.g., 0915 for September 15)
- Matrix (e.g., W or S for sediment or water)
- Team number (e.g. I9) and the sample number (e.g., 03 if it was the third station sampled)
- Thus, a water sample taken of September 7 as the 4th sample collected was labeled "LAAN37-A0907-WI904.

Sample ID labels were affixed to each container and covered with clear tape wrapped around the entire container circumference. Tape was also applied to secure the container lid. The collection of samples was recorded in both the SAV Site Characterization Form and in the NRDA Sample Collection Form for Soils and Sediments. All original field notebooks, forms, and notes, were preserved, signed, and dated by the field lead. If incorrect entry occurred, the original entry was

crossed out, dated, and initialed. All original records were gathered and kept on file by the trustees.

2.6.1 Chemistry Sample Labeling and Documentation

Sample labels were filled out in accordance with the sample ID protocol provided in the instructions from the trustee data management team. Sample ID labels were affixed to each container and covered with clear tape that was wrapped around the entire container circumference to ensure the label remained affixed to the sample container. Sample container lids were also taped as a security measure to insure against loss of sample due to a lid becoming loose. The collection of each sample was noted both in the SAV Site Characterization Form (Appendix A) and in the NRDA Sample Collection Form for Soils and Sediments. All original field notebooks, forms, and notes that were part of the study were signed and dated, and original copies were relinquished to the trustees. If entries were crossed out or corrected for any reason, the data logger initialed and dated the changes.

2.7 Sample Handling and Shipping

All collected samples were transferred to the sample intake team. Field sampling crews followed NRDA protocol documents for specific sample shipping and notification/sampling documentation instructions.

2.8 Preservation/Holding Times

All chemistry samples were immediately placed into coolers following sample collection and kept at 4°C. Samples were transferred to the sample intake team following the completion of field sampling to be frozen as soon as possible (for sediment and tissue chemistry samples). Water samples were scheduled to be analyzed immediately due to holding time limitations, while sediment and tissue samples collected for VOC and PAH analyses were archived for analysis in the event of oiling at JELA. Sediment samples collected for nutrient analyses were analyzed within the 28-day holding time.

Additional details on sample storage and holding times are available in the Analytical Quality Assurance Plan for the MS Canyon 252 (Deepwater Horizon) Natural Resource Damage Assessment.

2.9 Sample Analysis

Nutrient concentrations were analyzed in water and sediment samples by the University of Maryland System Chesapeake Biological Laboratory. Total N (organic nitrogen + ammonium + nitrate + nitrite) in water was measured by U.S. Geological Survey (USGS) method I-2650-03, and TP (all forms) in water was measured by USGS method I-4650-03, which involved alkaline persulfate digestion (Patton and Kryskalla, 2003). Sediment N was measured using an elemental analyzer following USEPA method 440.0 (Zimmerman et al., 1997). Sediment P was measured using high temperature hydrochloric acid extraction (Aspila et al., 1976).

2.10 Data Analysis

Flow data for the Davis Pond Diversion near Boutte, LA between February 2006 and September 2010 was obtained from the USGS Surface Water Database for Louisiana – http://nwis.waterdata.usgs.gov/la/nwis/uv?site_no=295501090190400. Nutrient data obtained from the USGS gaging station was used to calculate monthly loads of nitrogen (nitrite + nitrate) and phosphorus (total phosphorus) based on average daily flow rates through the Davis Pond diversion and average monthly concentrations of nitrogen and phosphorus in the Mississippi River near St. Francisville, LA. Calculated loads through the Davis Pond Diversion from 2007 through 2010 were based on concentrations derived from monthly loads. For the 2010 loads, average concentrations from the previous three years were used, since actual concentrations were not provided by USGS (i.e., the monthly nitrogen and phosphorous concentrations from May of 2007, 2008, and 2009 were averaged and multiplied times the flow to calculate the May 2010 loads).

Pearson Correlations were used to assess relationships between water quality parameters, SAV species richness, and FAV surface cover at JELA stations. T-tests were used to assess differences water quality parameters, SAV species richness, and FAV surface cover between JELA and reference stations. A two-way sample test for proportion (Alpha= 0.1) was used to determine statistical differences in SAV abundance between the 2006-2007 Poirrier et al. study and the Fall 2010 study (USEPA, 2006b).

3.0 RESULTS

Sampling of JELA and reference stations was performed over the course of five days from September 7 through September 11, 2010 between the hours of 0830 and 1600. JELA stations were sampled on September 7-9 and September 11, 2010. Reference stations were sampled over a 3-hour time period on September 10, 2010 between 1130 and 1410. Cloud cover ranged from mostly sunny to partially cloudy. Air temperatures across the study stations ranged from 31.1°C to 34.4°C. Photographs of stations surveyed are provided in Appendix A.

3.1 Water Quality

Water quality measurements for DO, pH, turbidity, salinity, conductivity, water depth, and Secchi depth at JELA and reference stations are provided in Appendix B.

3.1.1 Water Quality at JELA Stations

No oily sheens were observed at any of the stations in JELA. Water temperatures ranged from 26.8°C to 33.2°C. Water depth ranged from 0.30 m to 3.05 m, with an average depth of 0.98 m. Salinities significantly increased along a north to south gradient within JELA, ranging from 0.23 to 0.32 ppt (Table 3-1, Figure 3-1). Conductivity ranged from 0.263 to 0.657 mS/cm, significantly increasing along the north to south gradient. Dissolved oxygen levels decreased from north to south in JELA, ranging from 0.5 to 13.4 mg/L. More importantly, DO levels increased with time of day (Figure 3-2). Stations sampled in the morning (between 0900 and 1200) had an average DO level of 3.55 mg/L, while stations sampled in the afternoon (between 1200 and 1500) had an average DO level of 7.45 mg/L. Measurements of pH ranged from 6.65 to

8.65, with higher pH levels occurring at northern JELA stations, as evidenced by a significant correlation between pH and latitude.

Table 3-1. Correlations between Latitude and Physical Water Quality Parameters

Physical Parameter	Pearson's r-value	p-value
Salinity	-0.507	0.002*
Conductivity	-0.467	0.004*
Dissolved Oxygen	0.343	0.041*
pН	0.345	0.039*
Turbidity	0.181	0.299
Secchi Depth	-0.055	0.748

^{*}p-values ≤ 0.05 significant.

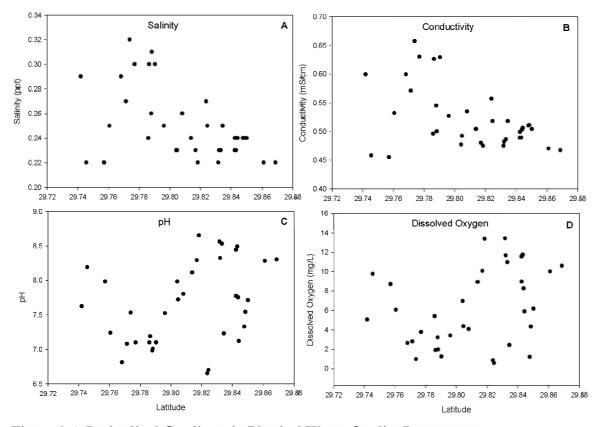


Figure 3-1. Latitudinal Gradients in Physical Water Quality Parameters

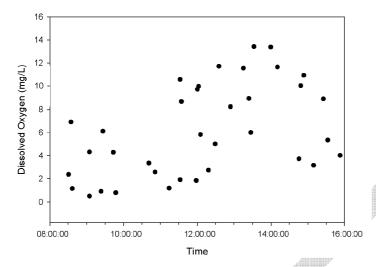


Figure 3-2. Relationship of Dissolved Oxygen Levels with Time of Day

There were no latitudinal gradients in light transmissivity measurements (i.e., Secchi depth and turbidity) within JELA (Table 3-1). Secchi depths ranged from 0.25 m at Station 29 to 1.10 m at Station 27. Secchi depths were within 0.5 m of bottom depths at 25 of the JELA stations. Eight stations had Secchi depths that were between 0.51 to 1.0 m shallower than bottom depths, and only two stations had Secchi depths that were over 1.0 m shallower than bottom depths. On average Secchi depths were 0.41 m shallower than bottom depths. Turbidity measurements ranged from 0 NTU to 47.5 NTU. Stations with higher turbidity levels had shallower Secchi depths (Figure 3-3, r = -0.512, p = 0.002). Dense FAV was associated with limited light penetration, as evidenced by a significant positive relationship between turbidity and percent cover of FAV (r = 0.387, p = 0.022).

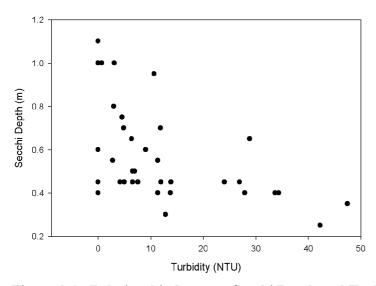


Figure 3-3. Relationship between Secchi Depth and Turbidity

3.1.2 Comparison of JELA Water Quality to Reference Stations

Water depths at the five reference stations ranged from 0.61 to 1.68 m. Salinity and conductivity were relatively consistent across reference stations, ranging from 0.12 to 0.19 ppt and from 0.263 to 0.396 mS/cm, respectively. Dissolved oxygen levels ranged from 1.39 to 6.22 mg/L. Secchi depths ranged from 0.35 to 0.80 m. Turbidity was generally low across all stations, ranging from 0.8 to 13.8 NTU. pH ranged from 6.86 to 7.87.

While most JELA and reference stations were positioned within marsh channels at locations with similar depths, the majority of physical water quality parameters differed significantly between JELA and reference stations (Table 3-2). All stations located within both JELA and the Bayou des Allemands and Humble Canal reference areas had freshwater conditions (i.e., salinities < 0.5 ppt) although the average salinity at JELA was significantly greater than that of the reference area. To limit time-of-day effects on DO levels, measurements of DO from JELA stations collected between 1130 and 1411 were compared to those of reference stations, which were collected between 1130 and 1410. Dissolved oxygen levels at JELA were more than twice as high on average as those at reference stations. Dissolved oxygen levels at four of the reference stations were lower than a threshold level below which adverse biological effects have been found to occur in estuarine systems (5 mg/L). Turbidity was over two-fold greater in JELA than reference areas, while Secchi depths were equivalent.

Table 3-2. Comparison of Physical Water Quality Parameters between JELA and Reference Stations

J	ELA Refere		ference	t-test
Mean	Std. Error	Mean	Std. Error	p-value*
0.98	0.09	0.99	0.20	0.954
0.25	0.01	0.16	0.01	0.002*
0.52	0.01	0.34	0.03	0.003*
8.27 ¹	0.92	3.65	0.85	0.002*
7.66	0.10	7.30	0.39	0.180
12.4	2.2	4.5	2.4	0.030*
0.57	0.04	0.57	0.20	0.982
	Mean 0.98 0.25 0.52 8.27 ¹ 7.66 12.4	0.98 0.09 0.25 0.01 0.52 0.01 8.27¹ 0.92 7.66 0.10 12.4 2.2	Mean Std. Error Mean 0.98 0.09 0.99 0.25 0.01 0.16 0.52 0.01 0.34 8.27 ¹ 0.92 3.65 7.66 0.10 7.30 12.4 2.2 4.5	Mean Std. Error Mean Std. Error 0.98 0.09 0.99 0.20 0.25 0.01 0.16 0.01 0.52 0.01 0.34 0.03 8.27 ¹ 0.92 3.65 0.85 7.66 0.10 7.30 0.39 12.4 2.2 4.5 2.4

p-value significant at 0.05

3.2 Mississippi River Flow and Nutrient Loading through Davis Pond Diversion

Loads of nitrogen and phosphorus entering JELA from the Mississippi River via the Davis Pond Diversion were examined from 2006 through 2010 to assess the presence of quantifiable increases in freshwater flows at the diversion and determine if increased flow through the diversion resulted in increased nutrient loads to JELA. As a result of the Mississippi Canyon Deep Water Horizon oil spill, freshwater flow was increased below the Davis Pond Diversion to help prevent oil from entering JELA from the first week of May through the first week of

¹ Mean for JELA stations sampled from 1130 – 1411

September 2010 (Figure 3-4). Flow increased from a daily average of 2,626 cubic feet per second (ft³/s) during April 2010 to 7,260 ft³/s during May 2010. From May 2010 through August 2010, the average daily flow of Mississippi River water through the Davis Pond Diversion was 6,824 ft³/s. Previous instances of sustained elevated flow rates through the diversion occurred in 2008 and 2009; however, those periods of high flow generally did not coincide with the summer high growth period for SAV.

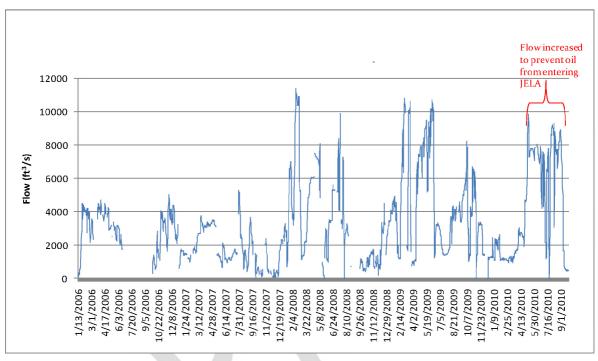


Figure 3-4. Average Daily Discharge of Mississippi River Flow into JELA through the Davis Pond Diversion.

The average monthly flow of water through the Davis Pond Diversion from February 2006 through September 2010 is shown in Table 3-3. In general, flow during May through August 2010 was two to four times higher than flow during these same months in 2007 and 2008. Although flow through the Davis Pond Diversion in May and June 2009 was similar to flow in May and June 2010, the July through August 2010 flow was more than twice the flow into JELA during the July to August 2009 period. Additionally, the total flow from May to August 2010 (7.02 billion ft³) was approximately 1.96 billion ft³ higher than the same period in 2009 (5.06 billion ft³).

Table 3-3. Average Monthly Flows of Mississippi River Freshwater in Cubic Feet through the Davis Pond Diversion.

Month	2006	2007	2008	2009	2010
Jan	no data	3,392,496,000	8,816,774,400	10,039,680,000	4,914,432,000
Feb	8,789,472,000	2,399,500,800			2,815,776,000
Mar	6,345,216,000	7,252,416,000	7,410,528,000	14,077,756,800	3,458,937,600
Apr	7,577,280,000	8,328,096,000	15,738,624,000	11,376,115,200	6,807,456,000
May	6,776,352,000	5,535,648,000	8,223,465,600	21,306,240,000	19,446,048,000
June	3,834,432,000	3,474,921,600	8,637,580,800	15,969,312,000	15,986,592,000
July	no data	4,032,288,000	9,862,560,000	5,266,944,000	13,519,362,240
Aug	no data	5,543,596,800	4,789,238,400	8,101,728,000	21,276,864,000
Sept	no data	4,168,540,800	246,067,200	8,208,864,000	7,022,764,800
Oct	3,307,046,400	868,320,000	1,977,609,600	12,742,272,000	
Nov	8,723,808,000	1,659,916,800	3,001,104,000	8,615,289,600	
Dec	8,677,152,000	2,612,476,800	4,668,192,000	2,244,767,040	
Total annual water volume					
(does not include days					
with no data)	54,030,758,400	49,268,217,600	92,353,824,000	103,356,432,000	95,248,232,640
# of Days with no data	142	41	67	20	6
Ave. water volume per day	242,290,396	152,062,400	309,912,161	299,583,861	356,734,954

Highlighting indicates time period in which flow was increased to prevent oil from entering JELA.

Monthly loads of nitrogen (nitrite + nitrate) and phosphorus (total phosphorus) were calculated based on average daily flow rates through the Davis Pond diversion and average monthly concentrations of nitrogen and phosphorus in the Mississippi River near St. Francisville, LA. The increased flow from May-August, 2010 resulted in substantially higher loads of nitrogen and phosphorus into JELA than had occurred in previous years (Table 3-4). The calculated nitrogen and phosphorus loads during May, June, and July in 2010 were approximately two times higher than calculated average loads for those same months during the previous three years (2007-2009). The calculated nitrogen and phosphorus loads during August 2010 were approximately 2.5 to 3.5 times higher than calculated average loads for August 2007, 2008, and 2009.

Table 3-4. Monthly Loads of Nitrogen (Nitrite + Nitrate) and Phosphorus (Total Phosphorus) entering JELA through the Davis Pond Diversion

Monthly NO2 + NO3 Load Calculations (Metric Ton or 1000 Kg)									
	2007 2008 2009 Avg (07-09) 2010								
May	299	320	693	437	813				
June	145	355	516	339	613				
July	124	420	179	241	484				
Aug	134	154	179	156	556				
Monthly Total P L	oad Calculations (I	Metric Ton or 1000	Kg)						
	2007	2008	2009	Avg (07-09)	2010				
May	43.1	39.6	87.8	56.8	108.4				
June	23.2	48.1	71.2	47.5	89.1				
July	33.2	69.8	27.0	43.3	92.1				
Aug	35.5	37.2	36.0	36.2	132.0				

3.2.1 Water Nutrients

Within JELA, TN concentrations ranged from 0.39 to 1.69 mg/L with a mean of 0.99 mg/L, while the reference stations ranged from 0.95 to 1.71 mg/L with a mean of 1.18 mg/L (Figure 3-5). No statistically significant differences were evident between TN concentrations measured at JELA stations and reference stations (t-test, p = 0.28). Across the 10 JELA stations, TP concentrations ranged from 0.058 mg/L to 0.283 mg/L with a mean of 0.137, while TP concentrations at reference stations ranged from 0.099 to 0.410 mg/L, with a mean of 0.188 mg/L. Once again there were no significant differences in phosphorous concentrations between JELA and reference stations (t-test, p = 0.31). Additionally, no latitudinal trends in either TN or TP concentrations were apparent at JELA stations.

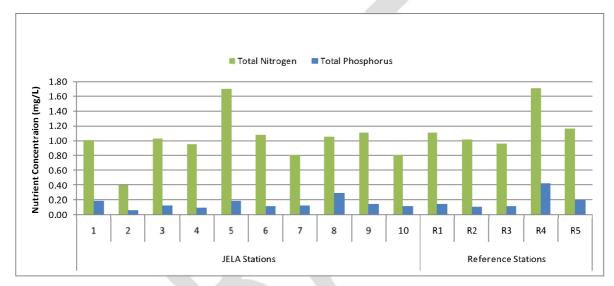


Figure 3-5. Total Nitrogen and Total Phosphorus Concentrations in Water

3.2.2 Sediment Nutrients

Sediment nutrient concentrations did not differ substantially between JELA and reference stations. Total nitrogen concentrations at JELA stations ranged from 0.36 to 1.28 mg/L with a mean of 0.83 mg/L, while concentrations at reference stations ranged from 0.42 to 1.09 mg/L with a mean of 0.68 mg/L (Figure 3-6). Total phosphorus sediment concentrations at JELA stations ranged from 0.058 to 0.283 mg/L with a mean of 0.137, while total phosphorus concentrations at reference stations ranged from 0.099 to 0.410 mg/L, with a mean of 0.188 mg/L. No statistically significant differences were evident in TN (t-test, p = 0.42) or TP concentrations (t-test, p = 0.20) between JELA and reference stations. Additionally, there were latitudinal gradients in sediment concentration within JELA.

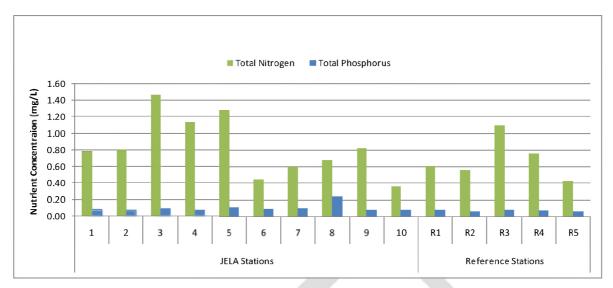


Figure 3-6. Sediment Total Nitrogen and Phosphorus Concentrations at JELA and Reference Stations

3.3 SAV Assessment and Distribution in JELA

Eight SAV species were observed within JELA, including six native species:

- Cerratophyllum demersum
- Najas guadalupensis
- Cabomba caroliniana
- Vallisneria americana
- Heteranthera dubia
- Potamogeton pusillus

and two exotic species:

- Hydrilla verticillata
- Myriophyllum spicatum

The most commonly observed SAV species was C. demersum, which was present at 97% of stations and in 85% of all quadrats (Figure 3-8). C. demersum occurred with all other SAV species within the JELA. The second most common



Figure 3-7. SAV collected for identification using a long-handled rake.

species was *N. guadalupensis*, which occurred at 75% of stations, followed by *H. verticillata* at 72% of stations, and *C. caroliniana* 69% of stations. These three species also occurred with all other SAV species within JELA. The SAV species *M. spicatum* and *V. Americana* were observed at approximately 25% of JELA stations, while *H. dubia* occurred at 11% and *P. pusillus* at 6% of stations. Occurrences of SAV and FAV at stations are reported in Appendix C.

The reference area contained a substantially lower diversity SAV community than JELA. Only two species of SAV, *C. demersum* and *N. guadalupensis*, were observed at the five reference stations. *C. demersum* was observed at 80% of reference stations (i.e., four of five stations), while *N. guadalupensis* was observed in 60% of stations (Figure 3-8). No SAV was observed growing at reference station R4.

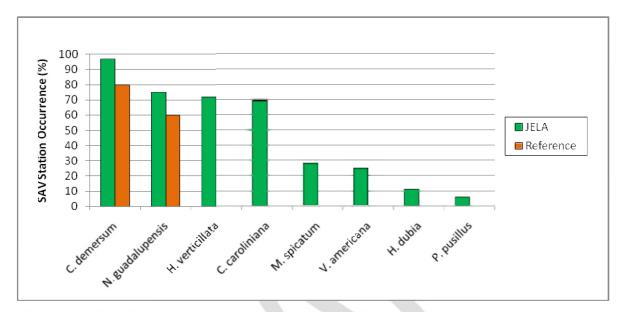


Figure 3-8. SAV Occurrence in JELA and Reference Stations.

SAV diversity within JELA was greatest at Station 8 where seven species occurred, followed by Station 7 where six species were observed (Figure 3-9). These two stations were located along the northern portion of Lake Salvador shoreline (Figure 3-10). Ten stations had five SAV species and 13 stations had four species. Low-diversity SAV communities were also observed at two stations at the southern end of Lake Salvador (Stations 21 and 27). Stations 3 and 28, located at the northern extent of Parallel Canal, had low SAV diversity, 0 and 1 species, respectively, likely as a result of 100% coverage of FAV. The dense abundance of floating plants on the water's surface may prevent adequate light penetration to sustain SAV at these stations. Similarly, low SAV diversity was observed in Kenta Canal which also had dense FAV coverage. Only one SAV species (*C. demersum*) occurred at Stations 5 and 29 on Kenta Canal.

Within the reference area, two SAV species were detected at Stations R1, R3, and R5, while only one species occurred at Station R2 and no species occurred at Station R4 (Figure 3-9, Figure 3-10). SAV species richness within the reference area $(1.4 \pm 0.4 \text{ species}, \text{mean} \pm \text{standard error})$ was significantly lower than that of JELA $(3.8 \pm 0.2 \text{ species})$ (t-test, p = 0.001).

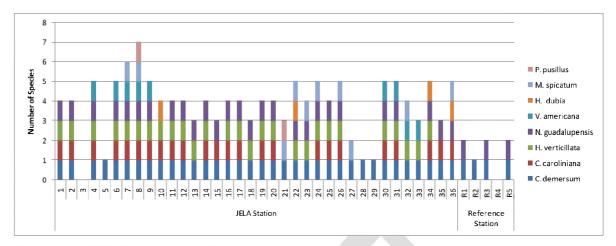


Figure 3-9. SAV Diversity at JELA and Reference Stations.

Species richness for SAV generally was greatest along the western portion of JELA and decreased moving east into the canals, evidenced by a negative correlation of SAV species with longitude (r = -0.361, p = 0.031). There was no significant change in SAV species richness along the north-south axis of the preserve. The majority of stations located along the shorelines of Lake Cataouatche and the upper portion of Lake Salvador had four or more SAV species. The most prevalent species, *C. demersum*, *N. guadalupensis*, *C. carloniana*, and *H. verticulata*, occurred throughout all areas of JELA (Figure 3-10). *H. dubia* occurred in the northern portion of JELA along the shoreline of Lake Cataouatche and within the inland channels. *M. spicatum* occurred along the shorelines of Lakes Cataouatche and Salvador, as well as one station at the northern portion of Bayou Segnette. *V. americana* occurred in the western portion of JELA at three stations along Bayou Segnette, five stations on the northern shoreline of Lake Salvador, and one station (Station 4) on Pipeline Canal. *P. pusillus* was only observed at two stations located along the shoreline of Lake Salvador.

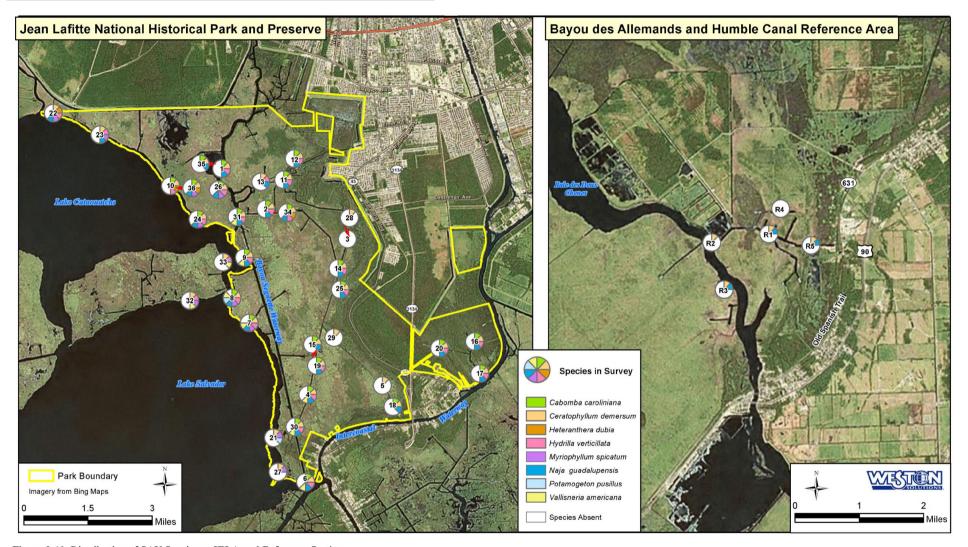


Figure 3-10. Distribution of SAV Species at JELA and Reference Stations.

3.3.1 Floating Aquatic Vegetation in JELA

The common water hyacinth (Eichornia crassipes), giant salvinia (Salvinia molesta), common salvinia (Salvinia minima) and alligator weed (Alternantha philoxeroides) were the most commonly observed FAV observed within JELA. Within the reference area, commonly observed FAV species included: S. molesta, A. philoxeroides, sedge (Oxycarium cubensis), E. crassipes, S. minima, water primrose (Ludwigia sp.), and water lettuce (Pistia stratiotes).

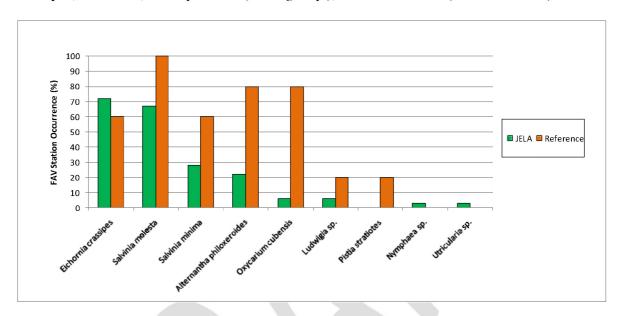


Figure 3-11. Occurrence of FAV at JELA and Reference Stations

In JELA, FAV percent cover within the quadrats ranged from 0 to 100 percent. FAV cover significantly increased along a west to east gradient within JELA (r = 0.475, p = 0.003). At stations where FAV cover was higher, SAV diversity tended to be lower, as evidenced by a significant negative correlation (r = -0.474, p = 0.004; Figure 3-12). All stations that had five or more SAV species had less than 60% FAV cover.

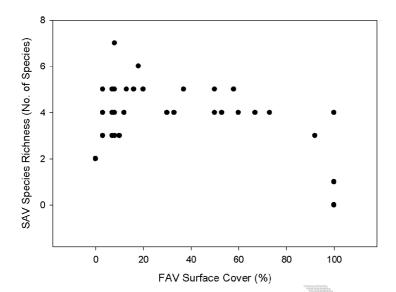


Figure 3-12. Relationship between JELA SAV Species Diversity and FAV Surface Cover

Within the reference area, FAV cover ranged from 50 to 80% within quadrats. Average FAV cover in the reference area was 60 + 6%, which was approximately 1.5 times greater than the average FAV cover in JELA (40 + 6%). Accordingly, FAV cover was found to be significantly greater in the reference area compared to JELA (t-test, p = 0.027).

3.3.2 Relationships of JELA SAV Community Structure to Physical Water Quality Parameters

Within JELA, stations that had higher diversity SAV communities had lower FAV surface cover (Table 3-5). Higher diversity SAV assemblages tended to occur in the western portion of JELA at stations with shallower depths. These stations tended to have higher levels of light transmissivity relative to station depth (as indicated by Secchi depth/station depth), as well as lower salinity and conductivity levels. Stations with greater SAV diversity also tended to have higher DO and pH levels, potentially resulting from lower surface cover of FAV, which may increase plant community respiration, particularly at nights.

Table 3-5. Correlations between Physical Station Parameters and Measures of SAV Community Structure

	SAV Species Ric	chness	FAV Percent Cover				
Parameter	Pearson's r-value	p-value	Pearson's r-value	p-value			
FAV Percent Cover	-0.474	0.004*					
Latitude	0.157	0.366	0.077	0.655			
Longitude	-0.361	0.031*	0.457	0.003*			
Station Depth	-0.344	0.040*	0.447	0.006*			
Secchi Depth	-0.190	0.268	-0.085	0.620			
Secchi Depth/Station Depth	0.340	0.042*	-0.644	0.000*			
Turbidity	-0.188	0.278	0.387	0.022*			
Salinity	-0.400	0.016*	0.317	0.054			
Conductivity	-0.336	0.045*	0.372	0.025*			
Dissolved Oxygen	0.427	0.009*	-0.549	0.001*			
pН	0.427	0.009*	-0.542	0.001*			
* Significant correlation at $p \le 0.05$							

3.3.3 Comparison of JELA Community Structure between 2006-2007 and Fall 2010 Surveys

3.3.3.1 Physical Water Quality Parameters

During the 2006-2007 Poirrier et al. study, salinity and Secchi depths were recorded at a number of stations (Poirrier et al., 2009). Salinities within JELA ranged from 0.2 to 1.3 ppt during the prior study, while in the Fall 2010 study, salinities ranged from 0.12 to 0.19. Thus, salinity conditions in JELA during the prior study ranged from fresh (\leq 0.5 ppt) to brackish (> 0.5 ppt), while during the Fall 2010 survey salinity levels were solely fresh.

Secchi depths ranged from 0.4 to 1.2 m in the 2006-2007 study and from 0.25 to 1.1 m in the current study. Therefore, it appears that there has been no notable change in light transparencies at JELA stations following the increase in freshwater flows from the Davis Pond Diversion.

3.3.3.2 Submerged Aquatic Vegetation Community Structure

A comparison of the relative abundance of SAV species between from the Poirrier et al. 2006-2007 study performed at 146 stations within JELA to the current Fall 2010 study was performed to assess potential impacts of increased flows of Mississippi River freshwater on JELA SAV community structure. The occurrences of the four most common SAV species (*C. demersum*, *C. caroliniana*, *N. guadalupensis*, and *H. verticillata*) significantly increased from the prior 2006-2007 study to the Fall 2010 study (two-way sample test for proportion at alpha = 0.1, Figure 3-13). The native SAV *C. caroliniana* increased in relative abundance by sevenfold, while the abundance the non-native *H. verticillata* nearly tripled. During both prior and current studies, native SAV species *C. demersum* and *N. guadalupensis* were the two most prevalent species within JELA.

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The relative abundance of three SAV species (*M. spicatum*, *V. americana*, and *H. dubia*) were statistically unchanged between the two studies. The non-native *M. spicatum* occurred at approximately 29% of stations during both surveys, while the native *V. americana* was found at 5% more stations in 2010 and the native *H. dubia* was at 6% fewer stations.

The native *P. pusillus* was the only SAV species to experience a significant decline in relative abundance between 2006-2007 and 2010 surveys, decreasing in occurrence from 17 to 6% of stations. Additionally two relatively rare SAV species from the 2006-2007 survey (*Egeria densa* and *Zannichellia palustris*) were not observed during the 2010 survey. The non-native *E. densa* was observed at two stations and the native *Z. palustris* was observed at one station in the 2006-2007 study. Thus, it is not surprising that they were not observed in the 36 stations assessed during the Fall 2010.

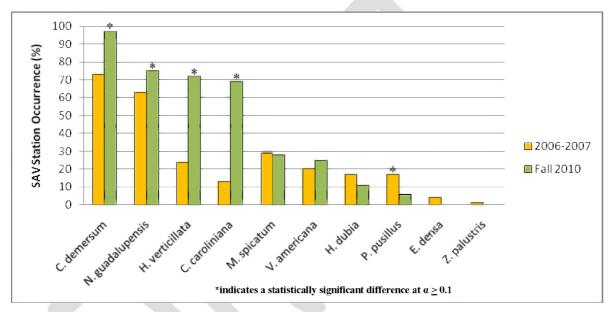


Figure 3-13. SAV Occurrence at JELA Stations during 2006-2007 and Fall 2010 Surveys.

3.3.3.3 Floating Aquatic Vegetation

During the 2006-2007 survey, Poirrier et al. identified 17 FAV species comprised of plants and algae (2009). Relative abundance data from stations was not reported for most FAV species during the 2006-2007 survey, with the exception of *S. molesta*. Giant salvinia is a rapidly growing invasive FAV species that is federally listed as a noxious weed. During the 2006-2007 survey, *S. molesta* was observed at ten stations (7% of stations) within the southern portion of JELA exclusively along the Bayou Segnette Waterway and lower Pipeline Canal. During the Fall 2010 survey, *S. molesta* was encountered at 26 stations (72%), with a range that extended nearly the entire north-south length of JELA throughout Bayou Segnette Waterway and Pipeline Canal, as well as along the shorelines of both Lakes Salvador and Cataouatche (Figure 3-14).

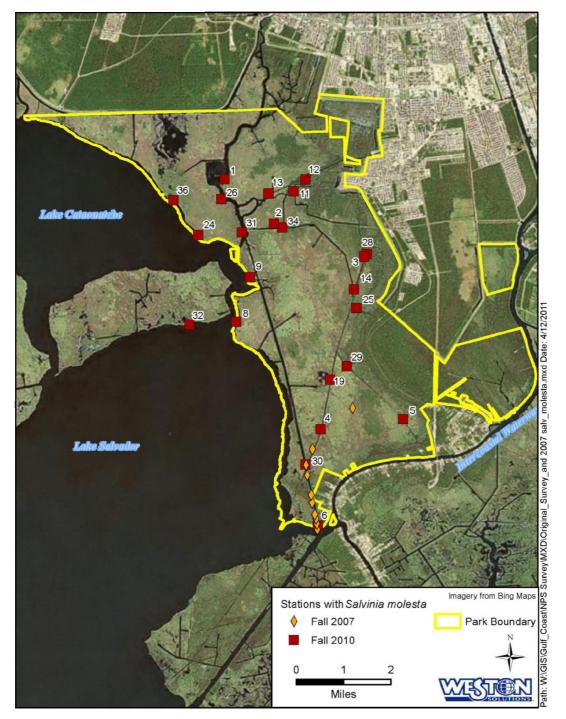


Figure 3-14. Comparison of $Salvinia\ molesta$ Occurrence between Fall 2007 and 2010 Surveys

4.0 DISCUSSION

In response to the MC 252 Oil Spill, more than 7 billion ft³ of Mississippi River freshwater was released from the Davis Pond Diversion to Lake Cataouatche and JELA from May to August, which was an increase of nearly 2 billion ft³ over the same period in 2009. Sustained increases in flow resulted in reduced salinities in JELA as well as increased loads of nitrogen by 879 metric tons and phosphorous by nearly 200 metric tons into the downstream system leading to JELA from May to August 2010. These changes in physical habitat conditions have coincided with changes in SAV community structure, including increases in abundance of non-native SAV and FAV species.

4.1 Water Quality

Evidence for response-driven reductions in salinity levels and other water quality parameters was apparent in JELA. These changes have important ramifications for SAV as well as the biota that inhabit the Preserve. Freshwater conditions (i.e., salinities < 0.5 ppt) extended throughout all areas of JELA during the Fall 2010 survey. Typically in the fall, salinity levels have ranged from fresh in the northern portion of the Preserve to brackish in the southern portion (Swarzenski, 2004; Poirrier et al., 2009). During the 2006-2007 Poirrier et al. survey (2009), salinities ranged from 0.2 to 1.3 ppt as compared to 0.23 to 0.32 ppt in Fall 2010. The loss of brackish conditions within the Preserve equates to a reduction in habitat heterogeneity, which may have resulted in a decreased capacity of JELA waters to support brackish fish species, since higher salinity waters have been found to provide habitat for estuarine species as well as early life stages and seasonal migrants of marine species (Schultz, 2006). Additionally, the increase in freshwater conditions may have facilitated the development of dense mats of surface vegetation comprised of FAV and SAV that reduced light transmissivity and DO levels. These changes have the potential to further undermine habitat quality for both SAV and other biota. Reduced light transmissivity reduces colonization depth of SAV (Dennison, 1987; Duarte, 1991) and favors the persistence of perennial plants with surface and near-surface growth, while undermining the recruitment and growth potential of annual SAV species (Poirrier et al., 2010). This can result in reduced diversity of the native SAV community. Additionally, the formation of dense surface mats of SAV and FAV can lead to reduced oxygen levels, often to concentrations (i.e., < 0.5 mg/L) that limit benthic and demersal fish and invertebrate communities (Schultz, 2006).

The sustained flows of Mississippi River freshwater from the Davis Pond Diversion substantially increased nutrient loads to downstream areas, potentially including Lake Cataouatche and JELA. Calculated nitrogen loads increased by nearly 900 metric tons over the same period in 2009. Calculated phosphorous loads from May to Aug 2010 increased by 200 metric tons over the same period in 2010. However, nutrient levels in the waters and sediments of JELA were not significantly higher than those of the reference area. Additionally, in comparing average TN concentrations (i.e., nitrite + nitrate + ammonia + organic nitrogen) in the water column between a prior USGS study conducted in 1999 and 2000 (Swarzenski, 2004) and the 2010 JELA survey, average concentrations were not substantially different. The average TN concentration in 1999-2000 study was 0.84 mg/L as compared to 0.99 mg/L in 2010. Therefore, the increased freshwater flows from the Davis Pond Diversion did not appear to substantially elevate nutrient

levels within the waters of JELA. This may have been due to the ability of the wetland system to rapidly assimilate nutrients into new vegetative growth.

Light availability (as measured by Secchi depths) was not reduced by increased freshwater flows into JELA. Secchi depths measured during the Fall 2010 survey were equivalent to those measured in the 2009-2010 survey (Poirrier et al., 2009), and Secchi depths did not differ significantly between the reference and JELA stations. While there were no notable changes in Secchi depths, light availability is an important factor that limits the depths at which SAV can survive (Cho and Poirrier, 2005); this was evidenced by the significantly lower diversity of SAV at deeper stations within JELA. This finding is consistent with the conclusion by Poirrier et al. that light availability did not appear to be adversely affected by the Davis Pond Diversion (2009).

4.2 Submerged Aquatic Vegetation

SAV community structure is known to be largely determined by physical habitat conditions, in particular salinity (Poirrier and Cho, 2005). Associated with the changes in salinity, there were several notable changes in SAV community structure since the 2006-2007 survey. Native and non-native SAV species that favor freshwater conditions have increased in abundance. These species include the natives *C. demersum*, *C. caroliniana*, and *N. guadalupensis*, as well as the non-native *H. verticillata*, which showed the most substantial increase in relative abundance within JELA, increasing by nearly threefold. There were also three SAV species that declined in abundance, including two natives (*P. pusillus* and *Z. palustrius*) and one non-native (*E. densa*). *E. densa* and *Z. palustrius* occurred at less than 5% of stations in the 2006-2007 study; therefore, their absence in the current study is likely due to reduced sampling effort in the Fall 2010 survey. Information on the SAV species observed in JELA during the Fall 2010 survey compiled from Poirrier et al. (2009; 2010) is provided as follows.

Ceratophyllum demersum (coontail) was the most prevalent SAV species in both the 2006-2007 and Fall 2010 surveys, and it significantly increased in occurrence at stations between the two surveys. This native plant is an important habitat-forming freshwater species that attaches to the bottom with rhizoids. Lacking true roots, plants are easily dislodged by wave action and currents. Increased freshwater flows may have benefited this species, reducing salinities and providing a transport mechanism for floating mats to other portions of JELA.

Najas guadalupensis (common water nymph) is a native species that occurs in both freshwater and brackish waters of JELA (< 3.5 ppt). This was the second most abundant species during both surveys, and it also significantly increased in abundance. Given this plant's tolerance for a wider range of salinities, it is likely that it will remain abundant throughout the Preserve as brackish conditions return.

Hydrilla verticillata (water thyme) is a non-native, highly invasive species that reproduces by fragmentation, seeds, turions, and tubors. It was previously found in the northwestern portion of JELA at stations with salinities ranging from 0.2 to 0.6 ppt. Reductions in salinity coupled with increased flows throughout JELA may have facilitated the southern and eastern expansion of this species throughout JELA. Although this species can provide habitat for fauna and food for waterfowl, it forms dense colonies that exclude native SAV species. This species may present a

management concern given its threefold increase in abundance within JELA and its ability to competitively exclude native SAV.

Cabomba caroliniana (fanwort) is a native freshwater-limited species (< 0.5 ppt) that was previously found at 13 interior stations east of Bayou Segnette. Reductions in salinity throughout JELA have allowed this species to increase in percent occurrence at stations by sevenfold and expand its range to most areas of JELA.

Myriophylllum spicatum (Eurasion watermilfoil) is a non-native nuisance SAV species that has the potential to displace native species. This species has a wide salinity tolerance, as it is reported to survive in waters with salinities up to 20 ppt. The overall distribution and abundance of this species did not change between the two surveys.

Vallisneria americana (water celery) is a native species that occurs in both fresh and brackish waters and does not form surface mats. Its relative abundance slightly increased between the two studies; however, there is concern that this species could be subject to competitive exclusion by mat-forming SAV and FAV following the winter dieback.

Heteranthera dubia (water star-grass) is a native species that slightly decreased in abundance since the 2006-2007 survey. This species can form large beds that provide habitat for invertebrates, fish, and waterfowl.

Potamogeton pusillus (baby pondweed) was the only SAV species to significantly decline in abundance since the 2006-2007 study. This species is tolerant of higher salinities (up to 3.5 ppt), and generally is more prevalent in the late winter and early spring before decreasing in abundance during the summer and fall (Poirrier et al., 2010). Thus, the observed decline of *P. pusillus* is more likely a seasonal shift than a response to increases in flows of Mississippi River to JELA. Follow-on studies performed in the spring will be useful in testing this assertion.

4.3 Floating Aquatic Vegetation

One of the most pronounced changes in the JELA FAV community was the substantial increase in the abundance of the federally-listed noxious weed, *S. molesta*. This non-native and invasive species was originally observed at only ten stations located within the southern portion of JELA in September 2007. Since that time it has spread throughout JELA, and now occurs along the entire length of the Bayou Segnette Waterway and Pipeline Canal, as well as along the lake shorelines. Additionally, *S. molesta* was found at all stations within the reference area. This species has the capacity to dominate areas with slow-moving water, forming dense mats that overgrow and shade native species (Poirrier et al., 2009). Additionally, it is of particular concern because it does not appear to be salinity limited within JELA, as it can survive in salinities up to 7 ppt (Poirrier et al., 2009). Therefore, abundance of this species may not decline with decreases in freshwater flows to JELA, potentially requiring other management actions.

4.4 Reference Area Assessment

The Bayou des Allemands and Humble Canal reference area was selected because it was located in close proximity to JELA and was not exposed to flows from the Davis Pond Diversion.

Additionally, both JELA and the reference area contained shallow channels of similar depth, and the reference area was located at a latitude that was consistent with the northern portion of JELA. However, the reference area had known preexisting limitations, including its proximity to agricultural areas that may provide sustained nutrients to the channels and, more importantly, its lack of existing data on water quality conditions and the SAV community.

The reference area was found to contain a low-diversity SAV community comprised of two species, C. demersum and N. guadalupensis, which were also the two most common species in Reference stations had higher FAV cover and diversity than JELA, including the presence of the noxious aquatic weed, S. molesta, at all stations. Water quality conditions also differed, as there were significantly lower salinities and DO levels and higher turbidity. The substantial differences in SAV community structure between the reference area and JELA paired with differences in water quality may be informative for predicting future potential habitat quality changes at JELA. First, there was a consistent negative relationship between SAV diversity and FAV cover. This was apparent when the reference area was compared to JELA, as well as when assessing the correlation between SAV diversity and FAV cover at JELA stations. Therefore, if the increased flows from the Davis Pond Diversion result in an increase in FAV cover, it is predicted that SAV diversity will also decline within JELA. Similarly, a continued increase in the spatial distribution of S. molesta within JELA may also coincide with reduced SAV diversity, potentially similar to the low-diversity assemblage of the reference area. Additionally, a shift towards greater FAV cover within JELA could also impact water quality, and in doing so would undermine habitat quality for associated fish and invertebrates that reside within the Preserve's waters. The strong relationship of lower DO levels in areas with higher FAV cover is predictable since higher density mats are unable to photosynthesize and produce oxygen at sufficient levels to counterbalance higher respiration rates. These predictions can be tested by follow-on studies.

While differences between the reference area and JELA can be informative, extreme care must be taken in inferring either the presence or absence of Davis Pond Diversion impacts from differences between JELA and the reference area based on one survey. First, there were preexisting differences between the reference area and JELA prior to the increased flow event. Second, the lack of pre-impact data for the reference area makes it impossible to assess differences in the trends or trajectories of community structure or water quality between the two areas using only one survey. This limitation can be reduced by performing repeated studies within JELA and the reference area to determine whether community conditions are converging, diverging, or remaining relatively constant.

4.5 Future Studies

Two follow-up field surveys are proposed in the spring and fall of 2011 to determine if significant changes within the SAV community have occurred following the increased freshwater flow to JELA as part of the MC 252 oil spill response action. Given seasonality of SAV growth, reproduction, and abundance, the impacts of the sustained increased flow of Mississippi River freshwater from the Davis Pond Diversion may be delayed. At the time of the increased flows (May to August 2010), a mature SAV community had reestablished following the winter dieback; therefore, follow-on studies are needed to determine if SAV recruitment and re-growth dynamics were impacted, since this response would be delayed. Surveys are proposed

to quantify physical and chemical water quality parameters, sediment and water nutrient levels, and potential shifts in SAV community structure and/or FAV species abundance as compared to reference stations, as well as the Fall 2010 and Poirrier et al. (2009) survey. Follow-on studies will also provide the opportunity to assess differences in SAV habitat and community trends between reference and JELA stations. In conducting these studies, it will be possible to assess evidence for seasonally distinct impacts to water quality and SAV abundance and species composition.



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APPENDIX A JELA and Reference Station Photographs

(Provided as a Separate Document)

APPENDIX B Physical & Chemical Water Quality

Water Quality Measurements and Conditions at JELA and Reference Stations

						Carabi	Datta				Bottom						W	/ater	Sec	diment
Station	Time	Date	Latitude	Longitude	Depth (m)	Secchi Depth (m)	Bottom Salinity (ppt)	Air Temp.(°C)	Conductance (mS/cm)	Bottom Temp.(°C)	Dissolved Oxygen (mg/L)	pH (pH units)	Turbidity (NTU)	Weather Cloud Cover	Oiled Cond.	Flowering Shoots	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Nitrogen (%)	Total Phosphorus (%)
1	9:44	9/9/2010	29.84868	-90.17147	0.71	0.75	0.24	31.1	0.511	30.58	4.27	7.54	4.6	Partly Cloudy	None	No	1.00	0.184	0.78	0.078
2	8:31	9/9/2010	29.83468	-90.15472	1.63	1.00	0.25	31.1	0.518	28.78	2.36	7.23	3.1	Partly Cloudy	None	No	0.39	0.058	0.8	0.068
3	9:48	9/7/2010	29.82385	-90.12327	2.54	0.95	0.27	31.1	0.557	26.84	0.77	6.65	10.7	Partly Cloudy	None	No	1.02	0.121	1.46	0.084
4	12:19	9/8/2010	29.77149	-90.14011	0.99	0.65	0.27	31.1	0.571	29.29	2.72	7.08	6.4	Partly Cloudy	None	No	0.94	0.085	1.13	0.067
5	9:24	7/8/2010	29.77394	-90.11115	0.81	0.35	0.32	31.1	0.657	28.29	0.89	7.53	47.5	Partly Cloudy	None	No	1.69	0.182	1.28	0.101
6	12:30	9/11/2010	29.74202	-90.14191	0.84	0.55	0.29	34.4	0.599	32.25	4.99	7.62	2.8	Sunny	None	Yes	1.07	0.103	0.44	0.084
7	10:42	9/11/2010	29.79626	-90.16219	1.52	1.00	0.25	33.3	0.527	30.78	3.34	7.52	0.7	Sunny	None	No	0.81	0.115	0.59	0.09
8	9:05	9/11/2010	29.80490	-90.16862	0.41	0.30	0.23	33.3	0.492	30.03	4.3	7.72	12.9	Sunny	None	No	1.05	0.283	0.68	0.236
9	14:00	9/9/2010	29.81844	-90.16347	0.71	0.45	0.22	32.2	0.475	33	13.34	8.65	5	Sunny	None	No	1.10	0.136	0.82	0.075
10	12:36	9/9/2010	29.84334	-90.19146	0.76	0.50	0.23	32.2	0.489	31.64	11.69	8.49	6.6	Sunny	None	No	0.81	0.103	0.36	0.079
11	12:06	9/7/2010	29.84441	-90.14751	1.22	0.70	0.24	32.2	0.506	29.88	5.81	7.12	11.9	Sunny	None	Yes	N/A	N/A	N/A	N/A
12	8:37	9/8/2010	29.84799	-90.14327	3.05	0.45	0.24	31.1	0.51	28.6	1.13	7.33	0	Partly Cloudy	None	Yes	N/A	N/A	N/A	N/A
13	12:55	9/7/2010	29.84390	-90.15637	1.17	0.65	0.24	31.1	0.503	30.3	8.2	7.75	28.9	Partly Cloudy	None	No	N/A	N/A	N/A	N/A
14	15:26	9/7/2010	29.81397	-90.12721	1.07	0.45	0.24	31.1	0.504	30.44	8.86	8.11	27	Partly Cloudy	None	No	N/A	N/A	N/A	N/A
15	11:33	9/8/2010	29.78840	-90.13789	0.91	0.60	0.31	31.1	0.5	28.57	1.89	7.01	0	Partly Cloudy	None	No	N/A	N/A	N/A	N/A
16	15:10	9/8/2010	29.78804	-90.07485	0.91	0.45	0.26	31.1	0.545	30.36	3.14	6.98	13.9	Partly Cloudy	None	No	N/A	N/A	N/A	N/A
17	14:46	9/8/2010	29.77721	-90.07310	1.02	0.80	0.3	31.1	0.63	30.14	3.7	7.1	3	Partly Cloudy	None	No	N/A	N/A	N/A	N/A
18	10:52	9/8/2010	29.76833	-90.10720	0.61	0.45	0.29	31.1	0.599	28.41	2.56	6.81	7.6	Partly Cloudy	None	No	N/A	N/A	N/A	N/A
19	11:59	9/8/2010	29.78662	-90.13634	0.61	0.45	0.3	31.1	0.626	29.43	1.82	7.19	12	Partly Cloudy	None	No	N/A	N/A	N/A	N/A
20	15:33	9/8/2010	29.78609	-90.08852	0.99	0.45	0.24	31.1	0.496	30.52	5.33	7.1	4.2	Partly Cloudy	None	No	N/A	N/A	N/A	N/A
21	11:35	9/11/2010	29.75728	-90.15387	0.46	0.40	0.22	34.4	0.455	31.83	8.63	7.98	0	Partly Cloudy	None	No	N/A	N/A	N/A	N/A
22	11:33	9/9/2010	29.86887	-90.23629	0.51	0.40	0.22	32.2	0.467	32.04	10.54	8.3	28	Partly Cloudy	None	No	N/A	N/A	N/A	N/A
23	12:03	9/9/2010	29.86118	-90.21838	1.37	0.60	0.22	32.2	0.47	31.12	9.95	8.28	9.1	Partly Cloudy	None	No	N/A	N/A	N/A	N/A
24	13:33	9/9/2010	29.83181	-90.18212	0.46	0.40	0.22	33.3	0.475	32.95	13.38	8.56	33.7	Partly Cloudy	None	No	N/A	N/A	N/A	N/A
25	15:53	9/7/2010	29.80821	-90.12647	0.61	0.40	0.26	31.1	0.535	30.15	4	7.8	13.8	Partly Cloudy	None	No	N/A	N/A	N/A	N/A
26	13:25	9/7/2010	29.84260	-90.17283	0.81	0.40	0.24	31.1	0.499	30.51	8.9	7.77	34.4	Partly Cloudy	None	No	N/A	N/A	N/A	N/A
27	12:01	9/11/2010	29.74565	-90.15247	1.37	1.10	0.22	34.4	0.458	31.43	9.69	8.19	0	Sunny	None	No	N/A	N/A	N/A	N/A
28	9:05	9/7/2010	29.82463	-90.12249	0.94	0.65	0.25	31.1	0.518	27.25	0.48	6.7		Partly Cloudy	None	No	N/A	N/A	N/A	N/A
29	11:15	9/8/2010	29.79054	-90.13033	1.07	0.25	0.3	31.1	0.629	29.41	1.17	7.1	42.3	Partly Cloudy	None	No	N/A	N/A	N/A	N/A
30	13:28	9/11/2010	29.76074	-90.14570	0.76	0.55	0.25	34.4	0.532	33.15	5.98	7.24	11.4	Sunny	None	No	N/A	N/A	N/A	N/A
31	14:11	9/7/2010	29.83225	-90.16592	0.61	0.45	0.23	31.1	0.482	30.87	11.62	8.32	24.1	Partly Cloudy	None	No	N/A	N/A	N/A	N/A
32	8:35	9/11/2010	29.80436	-90.18500	1.07	1.00	0.23	32.2	0.477	30.8	6.89	7.98	0	Partly Cloudy	None	No	N/A	N/A	N/A	N/A
33	14:49	9/9/2010	29.81702	-90.17032	0.66	0.50	0.23	33.3	0.48	32.21	10.01	8.29	7	Partly Cloudy	None	Yes	N/A	N/A	N/A	N/A
34	14:54	9/7/2010	29.83339	-90.15176	0.61	0.45	0.23	31.1	0.486	30.49	10.9	8.53	6.6	Partly Cloudy	None	No	N/A	N/A	N/A	N/A
35	9:27	9/9/2010	29.85033	-90.17363	1.14	0.70	0.24	31.1	0.504	30.32	6.09	7.71	4.9	Partly Cloudy	None	No	N/A	N/A	N/A	N/A
36	13:16	9/9/2010	29.84257	-90.18951	0.30	0.40	0.23	32.2	0.489	32.8	11.51	8.44	11.4	Partly Cloudy	None	No	N/A	N/A	N/A	N/A

						Secchi	Bottom			J.,	Bottom	рН					Water		Sediment	
Station	Time	Date	Latitude	Longitude	Depth (m)			Air Temp.(°C)	Conductance (mS/cm)	Bottom Temp.(°C)	Dissolved Oxygen (mg/L)	(pH units)	Turbidity (NTU)	Weather Cloud Cover	Oiled Cond.	Flowering Shoots		Total Phosphorus (mg/L)	Total Nitrogen (%)	Total Phosphorus (%)
R1	11:34	9/10/2010	29.85936	-90.47194	0.76	0.80	0.17	32.2	0.364	31.19	3.26	7.87	0.8	Partly Cloudy	None	No	1.1	0.141	0.6	0.071
R2	12:16	9/10/2010	29.85770	-90.48682	1.68	0.75	0.12	32.2	0.263	32.13	6.22	7.47	2.2	Cloudy	None	No	1.01	0.099	0.56	0.061
R3	12:57	9/10/2010	29.84702	-90.48385	0.61	0.35	0.13	32.2	0.279	31.34	4.83	7.23	4.2	Cloudy	None	No	0.95	0.105	1.09	0.077
R4	13:39	9/10/2010	29.86502	-90.46877	1.22	0.45	0.19	32.2	0.396	30.75	1.39	7.05	13.8	Cloudy	None	No	1.71	0.410	0.75	0.062
R5	14:10	9/10/2010	29.85659	-90.46111	0.69	0.50	0.18	32.2	0.373	31.38	2.54	6.86	1.6	Cloudy	None	No	1.15	0.186	0.42	0.055



APPENDIX C Submerged & Floating Aquatic Vegetation

Observed Submerged Aquatic Vegetation and Floating Aquatic Vegetation Coverage at JELA and Reference Stations

Station	Time	Date	Latitude	Longitude	Depth			Floating Aquatic Vegetation							
Station	Time	Date	Lantude	Longitude	(m)	C. demersum	C. caroliniana	H. verticillata	N. guadalupensis	V. americana	H. dubia	M. spicatum	P. pusillus	Coverage (%)	Salvinia molesta
1	9:44	9/9/2010	29.84868	-90.17147	0.71	X	X	x	X					50.0	X
2	8:31	9/9/2010	29.83468	-90.15472	1.63	X	X	X	X					60.0	X
3	9:48	9/7/2010	29.82385	-90.12327	2.54									0.0	X
4	12:19	9/8/2010	29.77149	-90.14011	0.99	X	X	X	X	X				53.3	X
5	9:24	7/8/2010	29.77394	-90.11115	0.81	X								100.0	X
6	12:30	9/11/2010	29.74202	-90.14191	0.84	X	X	X	X	X				36.7	X
7	10:42	9/11/2010	29.79626	-90.16219	1.52	X	X	X	X	X		x		18.3	
8	9:05	9/11/2010	29.80490	-90.16862	0.41	X	X	X	X	X		x	X	8.3	X
9	14:00	9/9/2010	29.81844	-90.16347	0.71	x	x	x	x	x				8.3	X
10	12:36	9/9/2010	29.84334	-90.19146	0.76	x	x	x			X			8.3	X
11	12:06	9/7/2010	29.84441	-90.14751	1.22	x	X	x	x					73.3	X
12	8:37	9/8/2010	29.84799	-90.14327	3.05	x	x	X	X					100.0	х
13	12:55	9/7/2010	29.84390	-90.15637	1.17	x		x	X					91.7	X
14	15:26	9/7/2010	29.81397	-90.12721	1.07	x	x	x	x					33.3	X
15	11:33	9/8/2010	29.78840	-90.13789	0.91	х	X		X					11.7	
16	15:10	9/8/2010	29.78804	-90.07485	0.91	X	X	x	X					66.7	
17	14:46	9/8/2010	29.77721	-90.07310	1.02	х	X	x	x	V				11.7	
18	10:52	9/8/2010	29.76833	-90.10720	0.61	x	x		x					6.7	
19	11:59	9/8/2010	29.78662	-90.13634	0.61	x	X	x	x					30.0	X
20	15:33	9/8/2010	29.78609	-90.08852	0.99	х	Х	X	X					100.0	
21	11:35	9/11/2010	29.75728	-90.15387	0.46	x						x	х	6.7	
22	11:33	9/9/2010	29.86887	-90.23629	0.51	x		x	x		х	x		13.3	
23	12:03	9/9/2010	29.86118	-90.21838	1.37	x		x	x			x		6.7	
24	13:33	9/9/2010	29.83181	-90.18212	0.46	х	х	x	x			x		6.7	X
25	15:53	9/7/2010	29.80821	-90.12647	0.61	x	x	X	x					73.3	х
26	13:25	9/7/2010	29.84260	-90.17283	0.81	x	х	X	X			х		50.0	X
27	12:01	9/11/2010	29.74565	-90.15247	1.37	x		/				x		0.0	
28	9:05	9/7/2010	29.82463	-90.12249	0.94	x								100.0	X
29	11:15	9/8/2010	29.79054	-90.13033	1.07	х								100.0	X
30	13:28	9/11/2010	29.76074	-90.14570	0.76	x	x	x	x	х				16.7	X
31	14:11	9/7/2010	29.83225	-90.16592	0.61	х	X	x	x	х				58.3	x
32	8:35	9/11/2010	29.80436	-90.18500	1.07	X		X		х		x		3.3	X
33	14:49	9/9/2010	29.81702	-90.17032	0.66	x		X		X				8.3	Х
34	14:54	9/7/2010	29.83339	-90.15176	0.61	x	x	x	X		x			20.0	х
35	9:27	9/9/2010	29.85033	-90.17363	1.14	X	X		X					3.3	X
36	13:16	9/9/2010	29.84257	-90.18951	0.30	X	X		X		х	х		3.3	Х

Station	Time	Date	Latitude	Longitude	Depth			Subme	rged Aquatic Vegeta	tion Species				Floating Aquatic Vegetation	
	Time	Date	Latitude	Longitude	(m)	C. demersum	C. caroliniana	H. verticillata	N. guadalupensis	V. americana	H. dubia	M. spicatum	P. pusillus	Coverage (%)	Salvinia molesta
R1	11:34	9/10/2010	29.85936	-90.47194	0.76	X			X					56.7	x
R2	12:16	9/10/2010	29.85770	-90.48682	1.68	x								50.0	x
R3	12:57	9/10/2010	29.84702	-90.48385	0.61	X			X					50.0	X
R4	13:39	9/10/2010	29.86502	-90.46877	1.22									80.0	x
R5	14:10	9/10/2010	29.85659	-90.46111	0.69	x			x					63.3	x





APPENDIX A JELA and Reference Station Photographs

JELA Stations

























Reference Stations



